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POWDERED ACTIVATED CARBON ADDITION AT THE WOODSTOCK WATER POLLUTION CONTROL PLANT

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Ministry
of the
Environment
Ontario

The Honourable
George R. McCague,
Minister

K.H. Sharpe,
Deputy Minister

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Powdered Activated Carbon Addition at the Woodstock Water Pollution Control Plant

by:

T. Alkema & R. Luscombe
Gore & Storrie Ltd.
Consulting Engineers
Toronto

Publication No. E.01

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Prepared For
Pollution Control Branch
Ministry of the Environment,
Ontario

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1. SUMMARY

During the summer of 1977, a full-scale plant trial of powdered activated carbon (PAC) addition to the secondary treatment section at the Woodstock Water Pollution Control Plant was conducted. PAC was added daily to both plant aeration cells, and a concentrated sampling and analyses program was conducted to document the impact of the PAC addition upon plant operation and effluent quality. Plant data prior to, during, and after PAC addition were monitored. The complete trial consisted of 18 study weeks, from May 8 to September 18, 1977.

It was found during the study that good operating results were obtained throughout the study period. No significant improvements in BOD_5 removal due to PAC addition was found. The concentration of heavy metals present in plant influent and effluent were monitored; it was found that PAC had practically no impact on heavy metal removal. The characteristics of the activated sludge culture in the plant were not altered significantly during the study period.

During the PAC addition period, the removal of colour in the secondary treatment section was much better than was the case prior to PAC addition. The test results also indicated that oxidation of NH_3-N was improved during the time that PAC was present in the system. This increased ammonia removal is of major importance at this water pollution control plant because a large percentage of the effluent total oxygen demand (TOD) is normally contributed by the nitrogenous oxygen demand (NOD).

As a tangent to the study, it was decided to monitor conditions in the anaerobic digesters as well. It was found that the operation of these units did not appear to be effected by the addition of PAC to the plant treatment system.

2. INTRODUCTION

During the last few years, several studies have been conducted on the effects of powdered activated carbon (PAC) addition to biological treatment systems. Early in the summer of 1977, the firm of Gore & Storrie Limited was engaged to provide for program planning, supervision, execution and report preparation of a project to investigate the effects of PAC addition to the secondary treatment plant section at the Woodstock Water Pollution Control Plant. This work was done on MOE Purchase Order No. A 49813, and was a joint effort between the City of Woodstock, Atlas Chemical Industries Limited, the Ministry of the Environment of Ontario and Gore & Storrie Limited.

The purpose of the study was to document the effect that PAC would have upon the operation and effluent characteristics at the Woodstock Water Pollution Control Plant (WPCP). This plant is a conventional activated sludge plant, which discharges its effluent to the Thames River. The limits for discharge from the WPCP are quite stringent, and it was felt by Atlas that PAC addition would possibly up-grade the operation of the plant.

The necessary field work and sample analyses which formed part of this project have been completed, and the results obtained and conclusions drawn are presented in this report.

3. PROCEDURE

3.1 Carbon Addition

The WPCP at Woodstock, Ontario, utilizes both primary and secondary treatment. Anaerobic sludge digestion is provided to stabilize excess sludge prior to land disposal.

A schematic flow diagram of the plant as it existed during the study period is shown on Fig. No. 1. During normal dry weather days the plant treats all the sanitary sewage discharged from the City of Woodstock; the plant flow is in the range of 4.5-5.0 MIGD.

When flow rates increase on wet-weather days, the flow rate through the primary treatment section is allowed to increase, but because of the limited capability of the secondary treatment section the primary effluent in excess of approximately 5 MIGD is by-passed and does not receive secondary treatment.

Powdered activated carbon (PAC) for this study was supplied by Atlas Chemical Industries Limited and was delivered to the site as a dry powder in heavy walled paper bags. In order to inject known quantities of PAC at the selected points, it was decided to slurry the carbon and then pump the slurry to the selected points shown on Figure 1. Two temporary rubber lined steel tanks, a slurry pump and two tank mounted mixers were provided by the Ministry of the Environment and installed at the plant. Calculations had been made by Atlas to determine the required PAC dosage each day; their program was followed throughout the study.

The daily operation of this carbon injection system was provided by the plant staff at the Woodstock WPCP and without their careful and consistent effort in this area the study would not have been possible.

3.2 Sample Collection

In order to gauge the effect of PAC on the operation of the WPCP, it was necessary to intensify the routine plant sampling. The sample collection points, the parameters measured on each sample, and the frequency of sampling are shown in the following table.

Sampling Location	Sampling Frequency	Parameters Measured
Grit Removal Effluent	4x/wk	pH, BOD_5, Sol BOD_5, total carbon, TOC, S.S., V.S.S., total P, NH_3-N, TKN, NO_2-N, NO_3-N occasionally heavy metals
Primary Clarifier No. 2 Effluent	4x/wk	pH, BOD_5, Sol BOD_5, total carbon. TOC, S.S., V.S.S., total P, NH_3-N, TKN, NO_2-N, NO_3-N. occasionally heavy metals
Secondary Clarifiers Effluent	4x/wk	pH, BOD , Sol BOD_5, total carbon, TOC, S.S., V.S.S., total P, NH_3-N, TKN, NO_2-N, NO_3-N, colour occasionally heavy metals
#1 & #2 Aeration Cell Contents	2x/wk	DO, temp, PAC concentration, oxygen utilization rate
Waste Activated Sludge	1x/wk	S.S., V.S.S.
Digested Sludge	1x/wk	S.S., V.S.S., total P, TKN occasionally heavy metals
Digester Supernatent	1x/wk	pH, BOD_5, Sol BOD_5, S.S., V.S.S., total P, NH_3- N occasionally heavy metals

The samples of grit removal tank effluent, primary clarifier effluent and secondary clarifier effluent were collected using automatic sampling equipment. At each location, a self contained vacuum type sampler was provided which took equal aliquots at one-hour intervals. The 24 aliquots were combined to form one 24-hour composite sample. It must be recognized that these samples were not truly composited according to flow. However, for comparative purposes this sample collection method was deemed adequate.

The sampling locations were chosen in consultation with the Ministry of the Environment and Atlas Chemical staff members. It should be recognized that "grit removal tank effluent" was sampled rather than raw sewage. This was done for two reasons:

(a) Sampling of the complete raw sewage stream entering the plant prior to digester supernatant and waste activated sludge application points was physically not possible.

(b) For the purposes of this study, it was of interest to know the total loading placed upon the treatment units including BOD_5 and suspended solids loadings due to in-plant recycle streams.

Samples of mixed liquor, waste activated sludge (WAS), digested sludge and digester supernatant were grab samples.

The analytical work was divided amongst the study participants. Samples of sewage, primary effluent and secondary clarifier effluent were transported to the Ministry of the Environment laboratories in Toronto and analyzed there. Samples of mixed liquor and WAS were taken by Atlas Chemical staff and analyzed either at the Woodstock water pollution control plant or at the Atlas Chemical laboratory in Brantford, Ontario. The samples of digested sludge and digester supernatant were taken by the plant staff and submitted to the Ministry of the Environment laboratory for analysis.

3.3 Data Presentation

The results from the analytical work completed by the various laboratories as well as the plant operating records were submitted to Gore & Storrie Limited for evaluation and report preparation. Throughout the 18-week study period, sewage and effluent samples were collected 4 times per week. This meant that approximately 70 samples were taken at each location, and that individual analyses results are available. To provide an overview of the study results, it was decided to tabulate the weekly mathematical average values for the various parameters. Upon review of all the individual data, it was found that this was a valid approach and adequately presented the test results obtained. These data are shown in Tables 1 through 7.

4. DISCUSSION OF RESULTS

4.1 Plant Operation During Pre-Test Period

In order to establish a base line for comparison, it was necessary to determine the various operating parameters at the WPCP prior to PAC addition. This was done during the period from May 9 to June 1, 1977. (Study weeks 1 through 4).

The primary treatment section of the plant is of sufficient capacity to handle the sewage flow and poses no operating difficulties.

The two primary clarifiers at the plant have a total surface area of 8900 ft^2. This means that the upflow rate at the usual plant flow of 4.8 MIGD was 540 gals/ft^2/day. This is well within the usual design limits for primary clarifiers. The plant operating staff had no difficulties with primary clarifier operation.

The secondary treatment section of the plant contains two aeration cells, with a total volume of 203,000 ft^3. The air is supplied by three piston-type blowers, with a total connected HP of 160. The effluent from the two aeration cells flows by gravity to two secondary clarifiers with a total surface area of 7,850 ft^2. Return activated sludge is pumped from these units by two return activated sludge pumps with a total connected HP of 13. No RAS metering is available; it is estimated that the total recycle rate is 200-300 Igpm. This means that the available recycle rate is approximately 6-10% of the plant flow.

The organic loading obtained in the secondary treatment section of the plant is shown in Table 3. The resulting F/M values are also shown. It was not possible from the available data to calculate solids retention time (SRT) because the rate at which activated sludge is wasted from the treatment systems is not known.

The plant includes two secondary clarifiers, almost circular in construction. One unit is 60' in diameter, the other 80'. This means that a total secondary clarifier area of 7,850 is available, yielding an upflow rate of approximately 610 gals/ft^2/day at a plant flow of 4.8 MIGD.

During previous years' experience, it has been found by the plant operating staff that it was necessary to maintain relatively low MLSS concentration (1000-1800 mg/l). If this is not done, the solids loading placed on the secondary clarifiers exceeds the sludge recycle capacity, and high secondary clarifier blankets with resulting solids wash-out occur.

The following summary of plant results during this pre-test period can be prepared:

	BOD_5	S.S.	NH_3-N
Primary clarifier influent	191	431	12
Primary clarifier effluent	82	117	12
Secondary clarifier effluent	19	<15	4.4

During this time period, conditions in the aeration section were quite consistent. The MLSS concentration was being maintained at approximately 1500 mg/l and the resulting SVI values hovered about 65 ml/g. The temperature in the aeration cells was about 16°C.

The anaerobic digester system functioned smoothly. The data obtained from WPCP data sheets, and the results of the lab work, are shown in Tables 6 & 7.

4.2 Plant Operation During Carbon Addition Period

On June 1, 1977, the addition of PAC to the aeration systems was started, and the following schedule was maintained:

June 1 - 9	500 lb/day
June 10 - 19	1000 lb/day
June 20 - 30	800 lb/day
July 1 - 5	0 lb/day
July 6 - 29	800 lb/day

An effort was made to divide the total weight of PAC added each day between the two aeration cells in proportion to the flow put to that treatment section. This was quite successful; the PAC concentrations found in the cells was quite even. Because of the common sludge recycle system, any possible errors in dosage would have evened out in any case.

Plant operation continued as before and no significant biological upsets due to carbon addition were noted. Plant operating methods and units in service were maintained as during the pre-test period.

During this carbon addition period, the PAC concentration in the mixed liquor steadily rose, and levelled off at about 300 mg/l. The MLSS (which included PAC) was maintained at approximately 1500 mgl, and the MLVSS also remained virtually unchanged. This meant that although the F/M values numerically were not altered from the pre-test period, the actual loading placed upon the activated sludge was increased by 20%.

The sludge settling characteristics were not materially effected by the PAC addition. This is shown by the SVI, which only decreased slightly to about 50-60 ml/g.

Due to warmer ambient conditions, the temperature in the aeration cells rose to 20°C.

From July 1 - 5, no carbon was added to the system. Difficulties with the activated sludge recycle system from the two secondary clarifiers was being experienced at that time, and the plant operating staff was of the opinion that the PAC could have had some influence on this. From the data it is not possible to confirm or deny this.

One item that must be noted at this time is the work and effort involved in handling the PAC. The material was brought to the site in bags and had to be slurried prior to application. This proved to be quite a labour intensive task; it took an operator approximately 1 hr/day to slurry the PAC, pump the slurry to the application point, and clean up the area. The most disagreeable aspect was the "dirtiness" of the operation and the clean-up required. With temporary equipment as used during this study, the daily chore of slurrying carbon and cleaning up the area was unpleasant. Any permanent operation would have to have much better materials handling systems to apply the PAC.

4.3 Plant Operation After Carbon Addition

On July 29, 1977, addition of PAC to the system was stopped. Collection and analyses of samples was continued until September 10, 1977 to determine whether the decrease of PAC in the system would affect the treatment results obtained.

No adverse effects due to stopping carbon addition were noted. The colour of the mixed liquor slowly returned to normal and plant operation proceeded as before. The hydraulic and organic loadings placed upon the various units in the plant remained the same, as can be seen from the data in Tables 1 and 3.

One change which was noted was the increase in NH_3-N concentration in the secondary treatment effluent. The ammonia concentrations are tabulated in Table 3. It can be seen that this value rose from approximately 0.5 mg/l to 4.0 mg/l in a time span of about 4 weeks.

4.4 Effect of PAC Addition upon BOD_5 Removal

From the data in Table No. 4, it can be seen that the addition of PAC did not have a significant effect upon the total BOD_5 or soluble BOD_5 of the secondary effluent. During the pre-test period as well as during the actual PAC addition period, reasonable results were obtained from the secondary treatment section of the plant.

There was an increase in % removal of BOD_5 through the whole WPCP as the study progressed. However, this increase was due to an increase in the raw sewage BOD_5 concentration rather than a further reduction in effluent BOD_5.

Included in the analytical work performed on the raw sewage and effluents were tests for total carbon (TC) and total organic carbon (TOC).

The results of these tests confirm the BOD_5 data, and show that the concentration of organics remaining in the secondary clarifier effluent was practically unchanged throughout the study.

During project review meetings, the possible presence of toxic compounds in the raw sewage stream was discussed, especially in connection with the results obtained in primary effluent BOD_5 analyses. It would appear from these results that a sudden increase in this primary effluent BOD_5 occurred, starting in week 5. Also, during the laboratory work required for the tabulated data, it was noted that on a number of occasions toxic conditions in the BOD bottles were indicated by the widely varying results obtained on different dilutions of the same sample. Normally this indicates that toxic or inhibiting material is present in the sample being tested.

A third observation made during the review of the laboratory data is the fluctuations in the ratio of TOC/BOD_5 which are shown in Tables 1, 2 and 4. It must be noted that fairly high ratios were found on primary influent and primary effluent during the pre-test period, and that the ratio decreased as PAC was introduced into the system.

While it is true that the above mentioned observations indicate that toxic compounds may have been present in the plant influent, the conclusion cannot be drawn with certainty. It must be remembered that no upsets related to toxicity were noted in the operation of the WPCP during this time. In fact, there has not been a history of difficulties in this regard at the plant. It can, therefore, be said that, although the possibility of toxicity removal by the PAC exists, the data collected during this study do not document it.

4.5 Effect of PAC Addition Upon NH_3- N Removal

The removal of ammonia (NH_3-N) from wastewater prior to discharge to the receiving stream is of importance at this WPCP because a major portion of the total oxygen demand of the secondary effluent can be due to nitrogenous oxygen demand (NOD) rather than to BOD. For this reason, oxidation of NH_3-N to oxidized nitrogen forms would be beneficial in reducing the oxygen demand on the stream.

The values for NH_3-N in the secondary effluent are shown in Table 4. It can be calculated that even though a fairly constant loading of NH_3-N and TKN was placed upon the secondary treatment section, the degree of NH_3- N removal increased as the study progressed.

This degree of ammonia removal was discussed in detail at a project review meeting during August, 1977. It was decided at that time that sampling and analyses should be continued after the addition of PAC was stopped on July 29, with special attention placed upon NH_3-N analysis results.

These results are included in Table 4, and indicate that ammonia oxidation during the time that PAC was in the system was significantly better than during the periods before and after carbon addition. It must be remembered, however, that the temperature in the biological reactor also gradually increased during May and June and that this may have had some influence upon NH_3-N oxidation.

Although the TOD of the effluent cannot be calculated from the information obtained during this study, it can be stated that a reduction in the NH_3-N in the effluent would mean a reduction in the TOD of the plant effluent as well. It was found towards the end of the PAC addition period that NH_3-N levels of the plant effluent were about 0.5 mg/l. When the PAC addition was halted, and the material slowly bled out of the system, the effluent NH_3-N level increased to about 4.0 mg/l. It can be calculated that this increase in effluent ammonia concentration represents a TOD increase of 760 lb/day.

4.6 Effect of PAC Addition Upon Colour Removal

Due to the presence of several textile related industries in the City of Woodstock, the sanitary sewage at times contains dye. This is a very visual contaminant; at times the sewage entering the plant is bright red, or blue or green.

Prior to PAC addition, small batches of dye could be removed by the activated sludge system, but often the secondary effluent became quite coloured due to slippage of dye through the system. Discharge of dye and subsequent colouration of the secondary effluent happen on a spasmodic basis and are therefore difficult to document numerically. However, several times a week the operators would notice coloured effluent.

When PAC was added to the treatment system, the removal of dye improved. During the 8 week period of carbon addition, coloured effluent was only noted on one or two occasions. Although this visual observation is a very imperical measurement method, there is no doubt that colour removal was fastly improved due to PAC addition.

During this study, an effort was made to document the actual colour removal obtained both during and after the PAC addition to the treatment system. The conventional method of colour measurement of natural raw water (comparison with a colour disc calibrated in Hazen units) is not applicable to wastewater colour due to dye discharges. For this reason, staff members from Atlas Chemical Industries performed more elaborate testing. The test procedures and results obtained are attached to this report in Appendix "A", and point to the fact that colour removal was better during the period that PAC was in the system.

4.7 Effect of PAC Addition Upon Heavy Metal Removal

On a few occasions during this study, special samples were taken for measurement of heavy metals in the plant influent and effluent. The analytical results are tabulated in Table 5. Only limited data are available, but the values listed indicate that no significant changes in metal concentration occurred due to PAC addition.

It should also be noted that in general the concentrations of heavy metals found in the secondary clarifier effluent were quite low during both test conditions, and that therefore very major improvement due to PAC would not be possible.

4.8 Effect of PAC Addition Upon Activated Sludge Characteristics

One of the main benefits of PAC in studies at other locations has been to drastically improve the settling characteristics of the activated sludge in the system. This, as much as anything else, has accounted for the significant improvements which have been demonstrated in some plants.

The measurements made in the aeration cells at the Woodstock WPCP are shown in Table No. 3. It can be seen that no major changes occurred. The only noticeable change was in colour from the usual brown to a grey-black colour. All other activated sludge characteristics remained virtually constant. It should be noted, however, that the SVI of the mixed liquor even before carbon addition was very low, indicating good settling characteristics.

4.9 Effect of PAC Addition Upon Aerobic Sludge Digestion

The raw sludge and WAS generated at the Woodstock water pollution control plant are stabilized by anaerobic digestion prior to ultimate land disposal. This means that the PAC injected into the activated sludge treatment system would ultimately find its way to the digesters.

The WPCP data sheets were utilized to provide information on the raw sludge pumped to the digester (see Table 6). During the pre-test period, the average conditions were as follows:

raw sludge pumped per week = 100,000 gals.
raw sludge pumped per day = 14,300 gals.
raw sludge total solids = 7.0%
raw sludge volatile solids = 56%
daily feed of volatile solids = 5,600 lb/day
primary digester volume = 60,000 ft^3
resulting loading rate = 0.09 lb VS/ft^3/day
resulting hydraulic retention time = 26 days

It can be seen that the loading on the digesters was relatively low. The process is quite stable; there have been practically no upsets in the

Woodstock digesters. Supernatant is displaced from the secondary digester, and returned to the WPCP influent prior to our raw sewage sampling location.

The quality of this supernatant is very much dependent upon the sludge haulage schedule. If the quantity of sludge hauled from the bottom of the secondary digester is almost the same as the amount of sludge displaced into the unit, reasonably good supernatant (<1.0% TS) can be achieved. However, if the supernatant flow rate is increased due to increased sludge pumping or decreased sludge removal, the supernatant quality rapidly deteriorates. During a large part of this study, and particularly during the carbon addition period, the rate of supernatant withdrawal was quite high, and consequently the TS in the supernatant were also high (>2.0% TS). This in turn caused a very high susp. solids loading in the primary clarifier influent, and accounts for the very high susp. solids levels recorded in Table 1.

The above conditions continued during both the pre-test and the test period, and were independent of the PAC addition.

The data in Table 6 show that there was a gradual increase in the volatile solids in the digested sludge both in the primary and secondary digester, but it is not possible to relate this to the PAC addition.

The gas production from the digester system is also tabulated in Table 6, and has been calculated as volume of gas produced per wt. of volatile solids fed to the digesters. It can be seen that the rate before and after the study period was slightly higher then during the PAC addition period. However, due to the very long residence time in the two digesters (in the order of 50 days) it is very doubtful whether the changes noted are actually significant, and they certainly cannot be related directly to the PAC addition.

Also included in the tabulated data is information on the secondary digester sludge and supernatant (Table 7). No concrete observations can be made, however, about direct benefits or disadvantages of PAC addition in the plant.

It is quite evident from the data in the Table and discussions with the operating staff that variations due to seasonal fluctuations and other plant operating techniques had much more effect on supernatant and sludge qualities, then the addition of PAC did. The digesters at the WPCP are adequately sized for the loading they receive, and were functioning well prior to PAC addition. The carbon neither hindered nor helped in this treatment process.

5. CONCLUSIONS

From the work performed during this study, and the data obtained, the following conclusions can be drawn:

a) The addition of PAC to the secondary treatment system at the Woodstock water pollution control plant did not materially reduce the BOD_5 and TOC concentrations obtained in the secondary clarifier effluent.

b) Indications are that significant improvements in NH_3-N oxidation were obtained, which would not have happened without PAC addition.

c) Colour removal from Woodstock sanitary sewage was substantially improved due to PAC addition.

d) There was very little noticeable difference in heavy metal removal due to PAC addition to the treatment system.

e) The addition of PAC did not significantly alter the activated sludge characteristics at this WPCP.

f) The operation of the anaerobic sludge digestion facilities was not affected by the PAC addition. However, it must be remembered that the study period was short in relation to the size and residence time of this unit process.

6. ACKNOWLEDGEMENTS

The assistance of the City of Woodstock, the Woodstock Water Pollution Control Plant staff, and Atlas Chemical Industries Canada Ltd. in the execution of this study, is acknowledged.

APPENDIX A

ATLAS CHEMICAL INDUSTRIES, CANADA, LTD.

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December 7, 1977

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G.R.C.
P.S.S.
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TA ✓

Gore & Storrie Limited,
Consulting Engineers,
1670 Bayview Avenue,
Toronto, Ontario M4G 3C2.

Attention Mr. T. Alkema

Re: PAC Study at Woodstock Sewage Treatment Plant

Dear Tom:

Attached is the colour data collected by us during and after PAC treatment. Five more values are to be obtained within the next two weeks and will be forwarded to you. As you can see, we have measured the colour at 422.2 nm (violet), 584.8 nm (yellowish-orange), and 645.9 nm (red) using a spectrophotometer. We then averaged the percent transmission for each wavelength and calculated the standard deviation of the average. Also listed are the Hazen unit colours carried out by the Ministry for comparison. A significant correlation is observed. Please also note that all readings were taken at a standard pH of 7.6. The findings clearly show a much better percent transmittance and less deviation during the carbon addition than during the post test period.

SECONDARY EFFLUENT

Date	Wavelength (nm) % Transmission		
uring Carbon Period)	422.2	584.8	645.9
June 28	99.2	100.0	100.0
June 29	99.2	99.0	99.5
July 5	97.0	97.5	98.0
July 6	97.5	98.0	99.0
July 8	97.3	98.1	99.2
July 14	97.8	98.0	99.2
July 20	99.0	100.0	99.5
July 22	98.5	99.2	100.0
July 27	98.9	100.0	100.0
Aug. 4	97.2	98.8	98.8
Aug. 10	98.8	100.0	100.0
Aug. 17	98.0	99.2	99.0
Aug. 19	98.1	99.2	99.2
(After Carbon Treatment)			
Aug. 24	96.8	98.0	97.8
Oct. 27	95.0	96.0	96.8
Nov. 3	94.8	95.8	95.2
Nov. 9	99.0	99.2	99.0
Nov. 29	96.0	97.0	96.5

Average & Standard Deviation

During Carbon Period = 98.2 ± 0.8 99.0 ± 0.9 99.3 ± 0.8

After Carbon Treatment = 96.3 ± 1.7 97.2 ± 1.4 97.1 ± 2.0

Average & Standard Deviation (Hazen Units)

During Carbon Treatment = 26 ± 5.5

Without Carbon Treatment = 35.6 ± 19.9

TABLE NO. 1

PRI. INFL. CHARACTERISTICS

WEEKLY AVERAGE OF COMP. SAMPLES

Study Week	Week Starting Sunday (1977)	Daily Raw Sewage Flow (avg for week)	pH	BOD_5 (total)	BOD_5 (sol)	Total Carbon	Total Organic Carbon	TOC/ BOD_5	Susp. Solids	Volatile Susp. Solids	P-total	NH_3-N	TKN	NO_2-N	NO_3-N	Temp.
		MIGD		mg/l	mg/l	mg/l	mg/l		mg/l	%	mg/l	mg/l	mg/l	mg/l	mg/l	°C
1	May 8	4.79	7.1	159	--	238	138	0.88	372	66	7.9	11	23	<0.01	<0.1	15
2	15	4.70	7.2	188	36	426	326	1.73	317	67	7.9	12	24	<0.01	<0.1	16
3	22	4.58	7.1	185	21	270	163	0.88	483	68	10.6	15	32	<0.01	<0.1	16
4	29	4.76	7.1	231	38	280	185	0.80	550	71	9.3	11	37	<0.01	0.8	17
5	June 5*	4.84	7.1	304	73	310	225	0.74	537	68	11.4	13	31	0.01	<0.1	18
6	12*	5.01	7.1	335	42	368	268	0.80	551	68	13	12	28	<0.01	<0.1	17
7	19*	4.77	7.1	258	31	443	350	1.36	588	70	10.3	14	28	<0.01	<0.1	18
8	26*	4.57	7.4	237	18	317	236	1.00	523	70	13	13	25	<0.01	<0.1	19
9	July 3*	4.56	7.2	215	20	230	116	0.54	516	71	10	12	26	0.01	<0.1	19
10	10*	4.72	7.2	235	30	170	85	0.36	438	73	11	11	26	<0.01	<0.1	20
11	17*	3.80	7.1	---	42	296	217	----	608	81	10	11	26	0.01	<0.1	18
12	24*	3.63	7.1	280	27	294	206	0.74	602	81	7	12	24	<0.01	<0.1	18
13	31	4.50	7.2	333	37	331	247	0.74	706	76	9	9	25	<0.01	<0.1	21
14	Aug. 7	5.35	7.2	329	22	199	125	0.38	586	78	8	5	18	<0.01	<0.1	21
15	14	5.01	7.5	356	18	342	271	0.76	726	68	19	7	31	<0.01	<0.1	19
16	21	4.56	7.1	403	49	302	221	0.55	677	75	12	10	31	<0.01	<0.1	20
17	28	4.39	7.3	308	55	278	190	0.62	479	74	9	10	27	<0.01	<0.1	21
18	Sept. 4	4.15	7.1	366	42	298	231	0.63	737	74	13	14	34	0.01	<0.1	20

NOTES: * denotes weeks during which PAC was added.

TABLE NO. 2

PRI. EFFL. CHARACTERISTICS

WEEKLY AVERAGE OF COMP. SAMPLES

Study Week	Week Starting Sunday (1977)	pH	BOD_5 (total)	BOD_5 (sol)	Total Carbon	Total Organic Carbon	TOC/ BOD_5	Susp. Solids	Volatile Susp. Solids	P-total	NH_3-N	TKN	NO_2-N	NO_3-N
			mg/l	mg/l	mg/l	mg/l		mg/l	%	mg/l	mg/l	mg/l	mg/l	mg/l
1	May 8	7.5	58	--	151	57	0.98	109	61	5.0	11	18	0.11	<0.1
2	15	7.4	80	25	184	178	2.22	108	61	5.7	13	20	0.01	<0.1
3	22	7.4	90	21	164	65	0.72	121	64	4.2	13	21	0.07	<0.1
4	29	7.5	98	22	159	73	0.74	129	63	5.6	12	19	0.40	<0.1
5	June 5*	7.4	128	42	146	61	0.48	131	62	5.0	12	19	0.21	<0.1
6	12*	7.4	130	21	146	73	0.56	136	65	6.8	12	22	0.03	<0.1
7	19*	7.4	145	28	190	98	0.68	171	61	6.7	15	22	0.02	<0.1
8	26*	7.6	130	21	147	52	0.40	151	61	6.9	13	21	0.08	<0.1
9	July 3*	7.3	153	15	167	89	0.58	166	63	5.8	10.5	20	0.05	<0.1
10	10*	7.5	125	16	130	50	0.40	135	67	5.9	12	19	0.07	<0.1
11	17*	7.6	124	12	130	57	0.46	112	73	4.1	10	16	2.6	0.4
12	24*	7.5	122	12	157	69	0.57	141	74	5.0	13	20	0.11	<0.1
13	31	7.6	103	14	145	69	0.67	111	66	5.3	11	18	0.12	<0.1
14	Aug. 7	7.7	58	8	105	45	0.78	96	58	3.8	7	12	0.51	0.6
15	14	7.9	112	8	101	37	0.33	120	63	5.5	8	16	0.89	0.4
16	21	7.7	91	12	120	45	0.49	104	62	5.1	10	17	0.26	0.1
17	28	7.8	109	25	139	55	0.50	111	72	5.5	10	20	0.56	<0.1
18	Sept. 4	7.7	102	16	126	47	0.46	108	70	5.7	12	20	0.15	<0.1

NOTE: * denotes weeks during which PAC was added

TABLE NO. 3

AERATION SYSTEM PARAMETERS

WEEKLY AVERAGE OF BOTH AERATION CELLS

Study Week	Week Starting Sunday (1977)	30 min. Settled Solids	MLSS	MLVSS	SVI	D.O. in Cells	PAC Conc.	Oxygen Uptake Rate	WAS		Mixed Liquor temp.	PAC Addition	Flow Rate to Sec.treat.	Aeration BOD$_5$ Loading	F/M Obtained (1)	F/M Obtained (2)
									Susp. Solids	Volatile Susp. Solids						
		%	mg/l	%	ml/g	mg/l	mg/l	mg/l/hr	%	%	°C	lb/day	MIGD	lb/day		
1	May 8	11	1760	63	63	--	nil	--	1.13	63	15	nil	4.67	2700	0.12	0.19
2	15	10	1506	60	66	--	nil	--	1.89	62	16	nil	4.67	3700	0.19	0.32
3	22	10	1570	68	64	--	nil	--	1.17	60	16	nil	4.53	4100	0.21	0.31
4	29	11	1550	58	71	--	<1	17	0.54	61	17	nil	4.55	4500	0.23	0.40
5	June 5*	9	1260	65	71	--	74	12.6	1.48	62	19	500	4.56	5800	0.36	0.55
6	12*	10	1770	66	56	2.5	290	20	1.31	62	20	1,000	4.70	6100	0.27	0.41
7	19*	10	1780	66	56	2.5	315	17.7	1.20	62	20	800	4.59	6700	0.30	0.45
8	26*	8.5	920	54	55	3.7	275	10.8	3.20	63	19	800	4.42	5700	0.49	0.91
9	July 3*	11	1837	63	63	2.9	260	17.7	1.53	62	20	400	4.37	6700	0.29	0.46
10	10*	11	1733	68	66	1.8	375	15	1.68	66	21	800	4.50	5600	0.26	0.38
11	17*	9	1244	69	58	5.3	319	10.5	1.50	68	19	800	3.77	4700	0.30	0.43
12	24*	5	1218	71	57	6.1	388	8.3	4.04	69	18	800	3.60	4400	0.29	0.41
13	31	7	1169	64	50	3.9	260	22.7	2.87	63	20	nil	4.25	4400	0.30	0.47
14	Aug. 7	9	1400	61	64	4.6	175	10.4	2.19	59	20	nil	5.07	2900	0.16	0.26
15	14	13	1015	56	40	5.9	90	4.2	2.42	56	20	nil	4.77	5300	0.41	0.73
16	21	13	1526	59	53	5.0	25	7.8	1.54	60	19	nil	4.52	4100	0.21	0.36
17	28	14	1291	--	66	--	--	--	--	--	--	nil	4.37	4800	0.29	--
18	Sept. 4	11	1640	--	67	--	--	--	--	--	--	nil	4.12	4200	0.20	--

NOTES: * denotes weeks during which PAC was added

(1) lb BOD$_5$/lb MLSS/day
(2) lb BOD$_5$/lb MLVSS/day

TABLE NO. 4

SEC. EFFL. CHARACTERISTICS

WEEKLY AVERAGE OF COMP. SAMPLES

Study Week	Week Starting Sunday (1977)		pH	BOD$_5$ (total)	BOD$_5$ (sol)	Total Carbon	Total Organic Carbon	TOC/ BOD$_5$	Susp. Solids	Volatile Susp. Solids	P-total	NH$_3$-N	TKN	NO$_2$-N	NO$_3$-N
				mg/l	mg/l	mg/l	mg/l		mg/l	%	mg/l	mg/l	mg/l	mg/l	mg/l
1	May	8	7.6	17	2	88	10	0.59	<15	--	1.5	6.4	7.9	0.75	5.2
2		15	7.4	25	4	57	<1	-	<15	73	0.9	3.5	4.4	0.79	7.8
3		22	7.4	19	6	84	13	0.68	<15	69	1.1	4.2	9.0	1.50	7.1
4		29	7.4	16	2	81	13	0.81	10	--	1.1	3.6	5.7	0.44	5.7
5	June	5*	7.6	28	10	75	8	0.29	<15	--	1.0	3.0	5.8	0.73	6.3
6		12*	7.5	19	5	83	11	0.58	15	70	1.1	3.4	4.8	0.89	8.2
7		19*	7.6	19	2	72	10	0.53	9	--	0.6	2.2	3.6	1.01	9.3
8		26*	7.5	32	9	68	12	0.38	11	75	2.6	2.3	3.2	0.93	9.5
9	July	3*	7.5	23	2.8	76	12	0.52	21	75	1.3	2.0	4.3	1.0	8.3
10		10*	7.4	17	1.9	80	15	0.88	11	67	1.5	0.8	2.3	0.40	10.4
11		17*	7.6	33	2	77	19	0.58	23	64	1.3	0.4	1.3	0.30	9.5
12		24*	7.7	20	1.9	71	8	0.40	13	55	0.9	0.6	1.3	0.47	13
13		31	7.5	26	2.3	75	13	0.50	11	66	0.9	1.4	2.1	2.04	7.9
14	Aug.	7	7.6	20	1.6	70	19	0.95	12	64	0.5	0.6	1.6	1.07	6.2
15		14	7.7	25	9.3	95	14	0.56	16	67	1.0	1.1	1.24	1.32	6.9
16		21	7.7	21	3.9	71	17	0.81	12	64	1.1	1.2	2.7	1.36	5.7
17		28	7.7	23	6.7	84	17	0.74	13	79	1.0	3.4	5.3	2.04	3.8
18	Sept.	4	7.6	26	2.7	78	11	0.42	13	69	1.1	4.2	4.9	1.27	5.9

NOTES: * denotes week during which PAC was added.

TABLE NO. 5

METAL ANALYSES RESULTS

INFLUENT & EFFLUENT STREAMS

Sampling Date - 1977	May 10	June 14	June 21	July 5	July 12	July 19	July 26	Aug. 23	Sept. 5	Sept. 6	Sept. 7	Sept. 8
Study Week	1	6	7	9	10	11	12	16	18	18	18	18
Pri. Influent												
Zinc	0.59	1.1		1.1	1.2	0.57	0.61	0.92	0.76	1.3	1.3	1.5
Copper	0.14	0.21		0.30	0.36	0.17	0.26	0.23	0.23	0.30	0.29	0.37
Nickel	0.12	0.05		<0.02	0.08	<0.01	<0.02	0.10	<0.04	<0.04	0.04	0.10
Lead	0.24	0.42		0.30	0.45	0.15	<0.03	0.22	0.17	0.25	0.28	0.34
Cadmium	0.02	0.02		0.02	0.02	0.01	0.01	0.02	<0.01	0.01	0.02	0.02
Chromium	0.07	0.20		0.13	0.32	0.08	0.05	0.20	0.10	0.11	0.13	0.26
Manganese	2.2	2.3		2.0	2.4	0.66	0.67	1.9	1.2	2.6	2.6	3.8
Fe				12	15		11	16				
Pri. Cl Effluent												
Zinc	0.10	0.70	0.50						0.24	0.44	0.36	0.44
Copper	0.04	0.11	0.12						0.12	0.13	0.10	0.12
Nickel	0.07	0.03	0.02						<0.04	0.08	0.03	<0.02
Lead	<0.02	0.17	0.15						<0.06	<0.06	0.06	0.08
Cadmium	<0.005	0.01	0.01						<0.01	<0.01	0.01	0.01
Chromium	<0.01	0.10	0.08						0.06	0.06	0.03	0.06
Manganese	0.12	1.1	1.1						0.25	1.0	0.83	0.84
Sec. Cl Effluent												
Zinc	0.27	0.16		0.14	0.14	0.19	0.20	0.18	0.11	0.09	-	0.09
Copper	0.08	0.05		0.09	0.08	0.06	0.08	0.07	0.04	0.04	-	0.04
Nickel	0.04	<0.02		<0.02	<0.02	<0.02	<0.02	0.04	0.01	0.01	-	0.03
Lead	0.09	<0.02		<0.02	<0.02	<0.02	<0.03	<0.05	<0.02	<0.02	-	<0.02
Cadmium	0.005	<0.01		<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	<0.005
Chromium	0.04	0.03		0.03	0.07	<0.02	<0.02	<0.04	<0.01	0.01	-	0.01
Manganese	0.08	0.12		0.26	0.07	0.11	0.05	0.10	0.12	0.11	-	0.13
Fe	-	-		1.4	0.65		1.4	0.80	-	-	-	-
Carbon Addition	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No

NOTES: (1) All values shown in mg/l.

TABLE NO. 6

SUMMARY OF SLUDGE AND DIGESTER SUPERNATENT FLOWS AND CHARACTERISTICS

(From WPCP Data Sheets)

Study Week	Week Starting Sunday (1977)	Raw Sludge			Pri.Dig. Sludge		Sec.Dig. Sludge		Gas Production		Vol. Solids Removal (raw to sec.dig.)	Sec. Dig. Supernatant		Dig. Sludge Hauled	
		gals.pumped x 1000	TS %	VS %	TS %	VS %	TS %	VS %	ft^3	ft^3/lb vs. fed	%	TS %	VS %	Loads	Gals x 1000
1	May 8	100	7.1	56	4.2	46.5	9.3	39	260,000	6.53	50	3.3	47	21	52.5
2	15	100	7.4	56	4.0	47.7	5.8	44	269.000	6.49	38	2.2	51	34	85
3	22	100	6.3	57	4.0	48.8	4.8	46	254,000	7.07	36	2.8	48	13	32.5
4	29	100	7.1	57	4.0	47.4	5.3	43	271,000	6.70	43	2.1	51	33	82.5
5	June 5*	100	7.4	56	4.0	47.1	6.0	46	248,000	3.98	33	1.9	50	32	80
6	12*	104	6.4	59	3.9	47.4	6.2	42	264,000	6.72	50	0.9	50	28	70
7	19*	105	7.7	56	4.2	49.3	5.4	47	239,000	5.28	30	4.1	48	14	35
8	26*	116	7.9	53	4.2	49.3	8.2	45	245,000	5.04	27	3.5	50	21	52.5
9	July 3*	116	6.9	58	4.1	50.8	6.1	49	231,000	4.98	30	3.6	49	33	82.5
10	10*	121	6.6	59	4.1	49.8	5.8	49	234,000	4.97	33	1.6	55	33	82.5
11	17*	127	-	-	-	-	-	-	253,100	-	-	-	-	36	90
12	24*	114	-	-	-	-	-	-	234,000	-	-	-	-	37	92.5
13	31	104	6.1	63	3.9	54.8	6.4	53	213,000	5.33	34	0.4	52	28	70
14	Aug. 7	92	9.3	52	3.8	53.2	10	48	184,000	4.14	15	0.34	53	29	72.5
15	14	81	6.0	58	3.3	54.9	5.9	52	172,000	6.10	22	0.34	51	28	70
16	21	68	7.4	51	3.2	50.3	7.2	51	164,000	6.39	0	0.41	55	25	62.5
17	28	82	6.9	60	3.4	54.4	4.0	52	215,000	6.33	28	0.35	53	33	82.5
18	Sept. 4	82	7.1	64	3.3	54.7	6.6	55	213,000	5.72	31	0.28	47	21	52.5

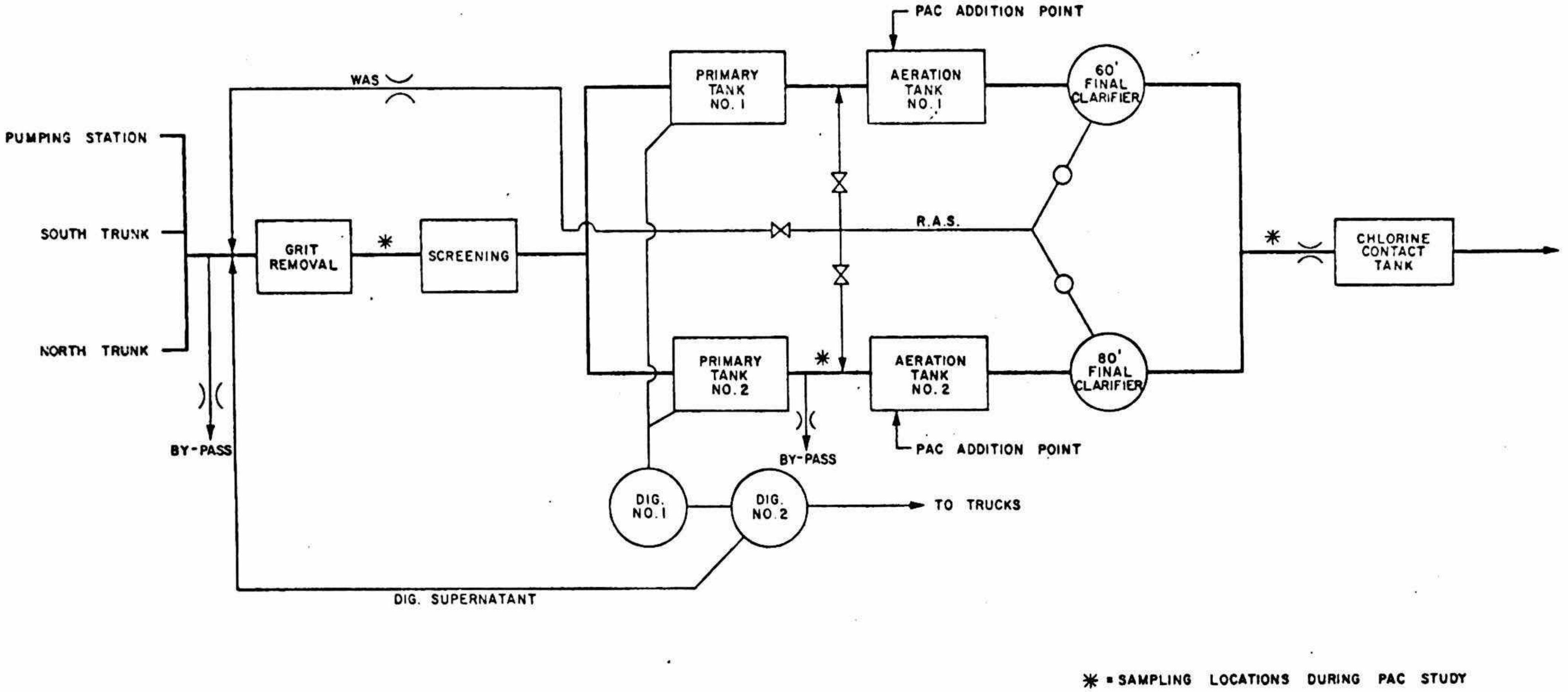
NOTES: * denotes week during which PAC was added.

TABLE NO. 7

ANALYSES RESULTS

DIGESTER SAMPLES

Sampling Date 1977	May 10	May 12	May 17	May 19	May 24	May 31	June 2	June 7	June 9	June 14	June 16	June 21	June 23	June 28	July 5	July 7	July 12	July 14	July 19	July 21
Study Week	1	1	2	2	3	4	4	5	5	6	6	7	7	8	9	9	10	10	11	11
Digester Sludge #2																				
Susp. Solids mg/l	49,550		64,070		70,600	43,280		44,250				62,950		68,800	73,400					
Vol. susp.solids %	44		20		41	42		42				45		44	46					
P Total mg/l	1,100				1,400	88		900		1,300		3,800		1,600	1,680					
TKN mg/l	1,700		1,700		1,800	1,800		1,500		2,400		2,800		2,200	2,300					
Zinc mg/l	130		70			56		130				200		160	180		200		160	
Copper mg/l	25		32			11		30				39		32	32		0.38		30	
Nickel mg/l	4.4		3.6			1.2		2.5				4.6		3.0	3.0		3.6		3.2	
Lead mg/l	56		61			6.5		49				100		55	65		65		55	
Cadmium mg/l	2.5		2.9			7.2		2.5				3.7		2.9	2.9		3.1		2.6	
Chromium mg/l	0.35		25			8.5		18				35		33	31		19		24	
Manganese mg/l	350		420			140		350				90		420	450		590		100	
Fe mg/l												4,000		3,500	3,100		2,700			
Digester Supn't.																				
pH mg/l	7.4	7.4	7.4	7.5	7.4	7.3	7.4	7.4	7.5	7.5	7.4	7.4	7.3		7.3		7.4			
BOD$_5$ mg/l		1,100	540	590	650	900	320	2,000	1,200	-	160	677	765			550				550
BOD$_5$ (sol) mg/l	165	44	50	220	190	500	50	65	100	-	36	20	20			260		60	200	146
Susp. solids mg/l	2,130	15,860	26,040	2,470	4,030	2,255	3,280	39,450	20,260	-	1,784	20,900	23,800	34,250	40,800	1,660	2,370			
Vol.susp.solids %	55	49	41	49	59	59	52	39	45	-	53	41	49	44	51	58	57			
P Total	58			65	84	60	87	680	420	85	100	450	480	450	580	47	65	54	53	160
NH_3-N mg/l	530	550	580	30	420	680	600	620	560		700	320		680	620	530	560			
Zinc mg/l	4.5							70		21										
Copper mg/l	0.79							17		40										
Nickel mg/l	0.15							1.8		0.42										
Lead mg/l	2.2							25		10										
Cadmium mg/l	0.10							1.5		0.48										
Chromium mg/l	0.75							10		5.0										
Manganese mg/l	12							290		9.5										
Fe mg/l										600										



SCHEMATIC FLOW DIAGRAM OF WOODSTOCK W.P.C.P.

FIG. 1

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756
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1978

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